Comparative analysis of navigation GPS receiver by GPS/GLONASS/EGNOS

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***Abstract*—This research is all about horizontal and vertical accuracy of five navigation GPS receivers, which were set up on the sport field of the University of Debrecen in February 2016. We used 37 points to determine positional accuracy. We compared the horizontal and vertical accuracy of the receivers in different modes. We estimated the point accuracy combined with GPS and GLONASS, with and without EGNOS. The EGNOS usages compare to the autonomous mode provide better accuracy horizontally, but not vertically. The average horizontal accuracy error values were between 0 and 3 m. The vertical component of absolute error showed that all satellites with EGNOS combination had the worst result. The vertical component of absolute error provided similar result in autonomous mode and in EGNOS-corrected mode between 0-4 m.**

***Keywords*—GPS accuracy; Global Positioning System; GPS receivers; positioning; horizontal; vertical**

I. Introduction

The Global Positioning System (GPS) has been used in the consumer and professional field too; that is why there are a lot of expectations of them. The accuracy of the GPS is dependent on the price of the receivers, or any other receiver specifications. The environment and outside factors can change the precision of the receivers (objects, trees, shape or deformation of the Earth, ionospheric electron content tropospheric water vapor). According all these factors the accuracy of the receivers changes constantly. The accuracy of the GPS can be provided by some applications e.g. single GPS satellites, GPS with GLONASS, EGNOS, different correction etc. In this paper the accuracy was compared by autonomous mode, GPS system, GPS with GLONASS system, application and not application of EGNOS system. Næsset found that the accuracy of the GPS combined with GLONASS, was much better than the accuracy obtained from single GPS measurements [1]. We can improve the accuracy with base stations. Basically the precision can provide extended number of the available satellites [2]. The condition of the receivers, the constellation of the satellites and the canopy can make different HDOP and VDOP [3]. In most cases GPS accuracy was tested by two methods, by autonomous mode and by Wide Area Augmentation System (WAAS). This system is the US-corresponding version of EGNOS. WAAS can improve the accuracy in clear sky condition, but it does not work well under forest canopy [4]. The use of WAAS has increased the value of the precisions with low-cost recreational-grade units, but it is difficult to forecast the rate and the affect in some cases [5]. WAAS availability is not appropriate near buildings or underneath tree canopy, because the receivers cannot accept signal near buildings or under tree canopy [6]. In research of Londe was mentioned that using WAAS got better horizontal component of the absolute error with Garmin unit [10]. Nevertheless, there are other options that improve the precision. Used the GPS–GLONASS simultaneously increased the accuracy [3, 5]. The GPS and COMPASS combination also can improve the positioning accuracy with some signal attenuation and limited satellite visibility condition [7]. Most of researches were based on the horizontal accuracy, but just few of them paid attention on the vertical accuracy [8, 9].

II. Material and Methods

A. Survey instrumentation

In this study five different types of commercial GPS receivers were used: Garmin eTrex 30, Trimble GeoExplorer XM, Trimble Juno SB, Ashtech Mobile Mapper 10, Stonex S9 and Focus 8 total station. There are different specifications for each receiver. I. Specifications of Ashtech Mobile Mapper 10: code phase, 20 channels, L1 antenna, low-cost receiver. II. Specifications of Garmin eTrex 30: code phase, 12 channels, L1 antenna, lowest-cost receiver between five of them. III. Specifications of Trimble Juno SB: post-processing correction, code phase, 12 channels, L1 antenna, medium - cost receiver. IV. Specifications of Trimble GeoExplorer XM: post-processing correction, code phase, L1 antenna, medium-cost receiver. V. Equipment's specifications of Stonex S9: real-time kinematic (RTK), carrier phase, 220 channels, L1, L2, L5 antennas, high-cost receiver. The coordinate system was

Hungarian EOV (EPSG: 23700). The reference positions were recorded by leveling equipment and Focus 8 total station.

B. Study area

The study area was a smooth and flat sport pitch, located in Debrecen, Hungary, at the University of Debrecen. This test consisted of 37 points in L-shaped “Fig. 1”.

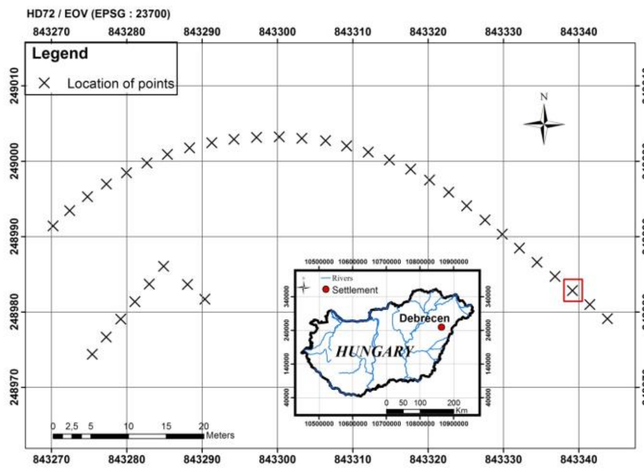

Fig. 1. Location of study area.

C. Data collection

Data collection was divided into two main parts. First collection was in autonomous mode, second part was the EGNOS, GPS-GLONASS, GPS-GLONASS and EGNOS combination. The recorded period was 1 minute. The data of the Garmin eTrex 30 and Trimble receivers provided data in WGS84 that is why we used an official online calculator named “EHT 2014 V.1.0” [11]. We used leveling equipment (with 28x zoom) and Focus 8 total station for reference data “Fig. 2”.

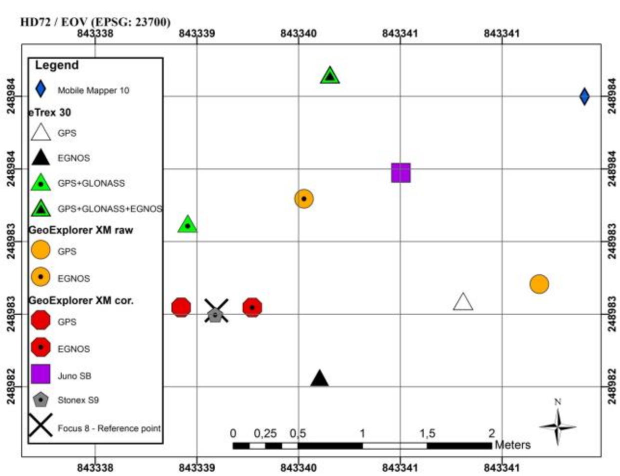

Fig. 2. Study area with some sample points.

D. Horizontal and vertical analysis

We calculated the horizontal and vertical accuracy among each GPS receivers and among approaches. Basic analysis was generated in Microsoft EXCEL as the mean, minimum, maximum, standard deviation of the distinctions one by one for each of the receivers.

First, we separated all measurements into two parts. The first part was the vertical accuracy, and second part was the horizontal accuracy. We used the total station and the leveling equipment for the vertical accuracy.

The horizontal accuracy also split into other two parts. The first one comprises of all autonomous measurements with each of the GPS receivers. The main value of this part is the mean accuracy for each of receivers, other category is all the measurements with Garmin eTrex 30 and Trimble GeoExplorer XM, which include the surveys with EGNOS correction.

III. Results and Discussion

A. Vertical accuracy

First comparisons were for databases of the Stonex S9, Garmin eTrex 30, the Trimble GeoExplorer XM data collection in code-corrected mode with vertical accuracy, which were based on the Focus 8 and the levelling equipment. The Trimble Juno SB collected only horizontal measurements for accuracy analysis. The results indicated that there is a difference among the two GeoExplorer XM files (between the original raw file and the differentially corrected files).

The mean vertical accuracy in 4 cases (1. eTrex in autonomous mode; 2. GeoExplorer correction in autonomous; 3. EGNOS-corrected mode; 4. Stonex S9) were less than 1 m. The Mobile Mapper 10 had the largest bias with 9.89 m, all in other case the mean was around 3-4 m. The range of standard deviation of the vertical accuracy is wide, the eTrex 30 in GPS+GLONASS logging mode had more straggler or outlier value than the other surveying. The GeoExplorer XM corrected data without EGNOS and with EGNOS-corrected mode, and the Stonex S9 surveys were more stable with smaller biases (less than 0.3 m) “Fig. 3”.

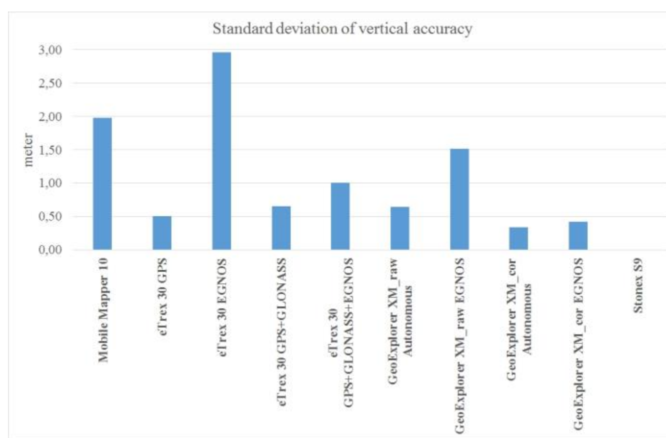

Fig. 3. Standard deviation of the vertical accuracy for Stonex S9, Garmin eTrex 30, Trimble GeoExplorer XM with 2 basis station values (GeoExplorer XM_raw, GeoExplorer XM_cor.).

The minimum and maximum vertical accuracy showed us similar distribution. Stonex S9 had the lowest result, as we expected (min: 0.0 m). The GeoExplorer, with code correction provided less than 2 cm bias in both cases. As we did not expect, the highest vertical deviation is more than 13 m with the Mobile Mapper 10 “Fig. 4”. As we show below, these excessive values of this equipment will appear at horizontal accuracy as well “Fig. 5”. The second highest value is the 8.78 m by the eTrex 30 in GPS + GLONASS mode.

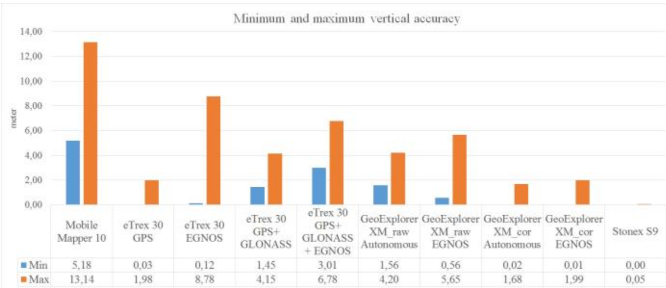

Fig. 4. Minimum and maximum vertical accuracy.

B. *Horizontal accuracy*

The study showed remarkable differences among these receivers. Hand-held receivers collected the horizontal accuracy in autonomous mode simultaneously. This ensured that the receivers provide more accurate result during the same condition.

The lowest result of the horizontal accuracy was provided by the GeoExplorer XM with EGNOS correction (0.61 m, “Fig. 5”. The eTrex 30 with EGNOS correction did not improve the horizontal accuracy. Andersen [5] mentioned the same conclusion that low-cost units had not real influence of the WAAS at the accuracy, just like in our case with EGNOS. Remarkable that the highest bias was with the GeoExplorer XM unit in autonomous mode; regarding the high quality of this receiver. After the differential correction the accuracy became fairly better. The status of satellite geometry or the number of the available satellites can modify the accuracy, as Næsset and Habrich determined before [1, 2]. That is why some combinations (such as the GPS and GLONASS combination) can modify and decrease the accuracy of the GPS receivers. Our results are the same as Andersen [5] had that using GLONASS can improve the accuracy. On the other hand, those values, when we used the 3 satellite systems (GPS, GLONASS, EGNOS) simultaneously, were the least favorable result among all the values. Using those one by one can improve the accuracy, but this combined satellite method doesn’t lead to higher accuracy. Furthermore, enhancing measuring interval can increase the accuracy as well. Our surveying’s interval was 1 minute, but most of other authors measured during 5-10-20-30 minutes or 1-2 hours, which can give better accuracy. Valbuena determined that with more than fifteen minutes recording can improve the accuracy [3]. Weih measured around 2 hours by Garmin eTrex and Juno, and his horizontal accuracy was enhanced comparing to ours, which proved the fact that longer surveying time can improve the accuracy [6].

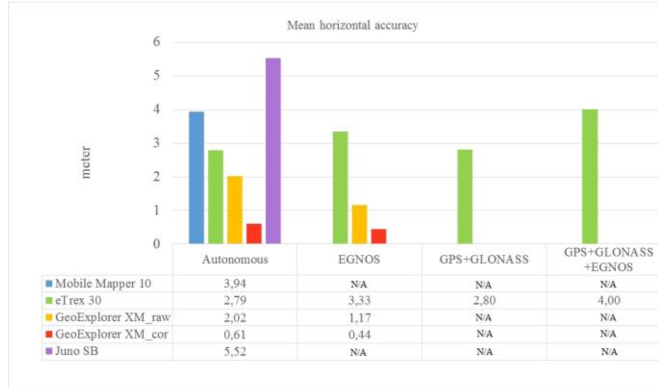

Fig. 5. Mean horizontal accuracy in different mode.

IV. CONCLUSION

This study showed that GPS, GLONASS and EGNOS system can modify the accuracy of receivers in different way in different aspect. The horizontal accuracy is not determined by the level of professionality of device by all means. Weih found the same conclusion that the interaction between accuracy and the cost of the receivers is minimal [6]. These results showed that the GPS error could be increased by some obstructions: the differential correction can decrease some GPS errors, but cannot handle the multipath or the receiver errors. We would require lower accuracy, especially with the GeoExplorer XM case. The GPS and GLONASS combination is a good option to improve the horizontal accuracy, using these 3 methods together (GPS, GLONASS, EGNOS), cannot improve the result. In case of the horizontal accuracy we can state out that using EGNOS is giving us the lowest result, so the EGNOS can increase the accuracy horizontally, but not vertically in our case. The EGNOS signal has an advantage by the GeoExplorer XM receivers, but did not show any improvement in case of eTrex 30.

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